Waseda University

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Ultra-Short Electron Bunch Generation by a Photocathode RF Gun

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Outline

1. **Introduction**
   - Ultra-Short Electron Bunch
   - What's THz wave?
   - Motivation of our Work
2. **Bunch Compression**
   - What's ECC RF Gun?
   - How does the Bunch get Compressed ?
3. **Experiment**
   - Accelerator System at Waseda
   - Generation of Coherent Radiation
4. **Summary**

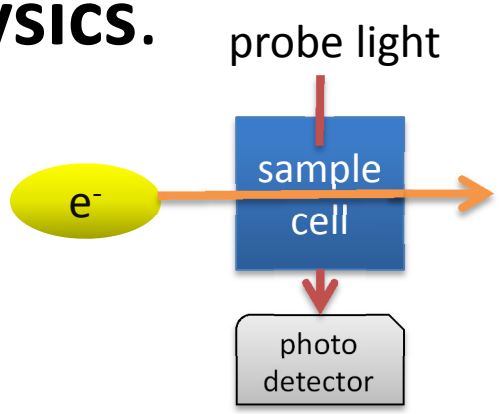
Introduction

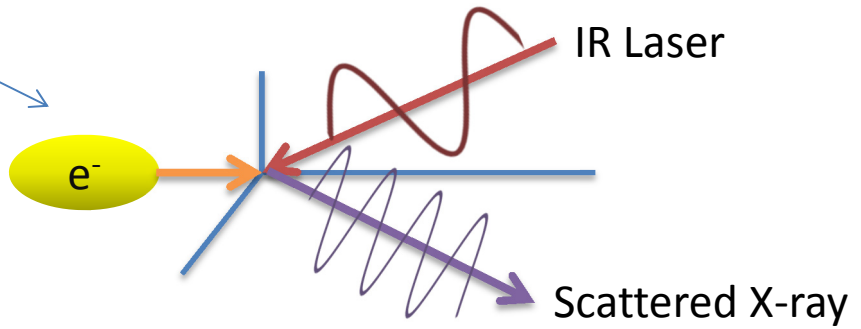
In Waseda University,

We're studying **accelerator physics.**

⇨ Some Applications

- Pulse Radiolysis
- Laser-Compton Scattering



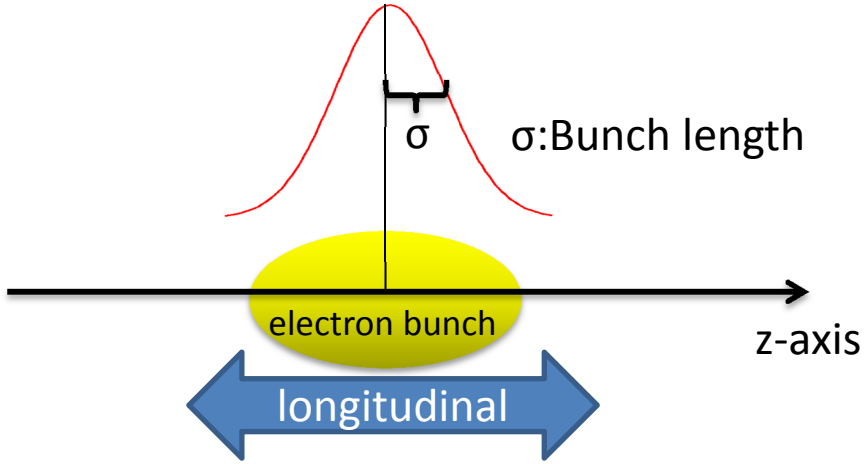


Furthermore,

⇨ **RF gun development**

We aimed to make a new RF gun which generates **ultra-short** electron bunch. ⇨ **For What?**

Ultra-Short **electron bunch** leads to…



improve

- the temporal resolution of Pulse radiolysis
- the luminosity of Laser-Compton Scattering

(at least in our Lab.)

And…

generate High Power Coherent THz waves!

Coherent THz Radiation

Short Electron bunch

Coherent Radiation

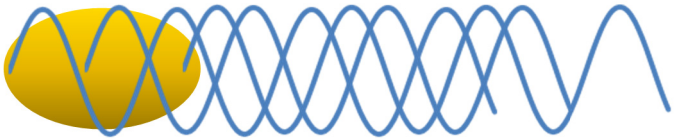
$\sigma < \lambda \rightarrow \boldsymbol{I_{coh} \propto N^2}$

$\times \boldsymbol{N}$ N: number of electrons

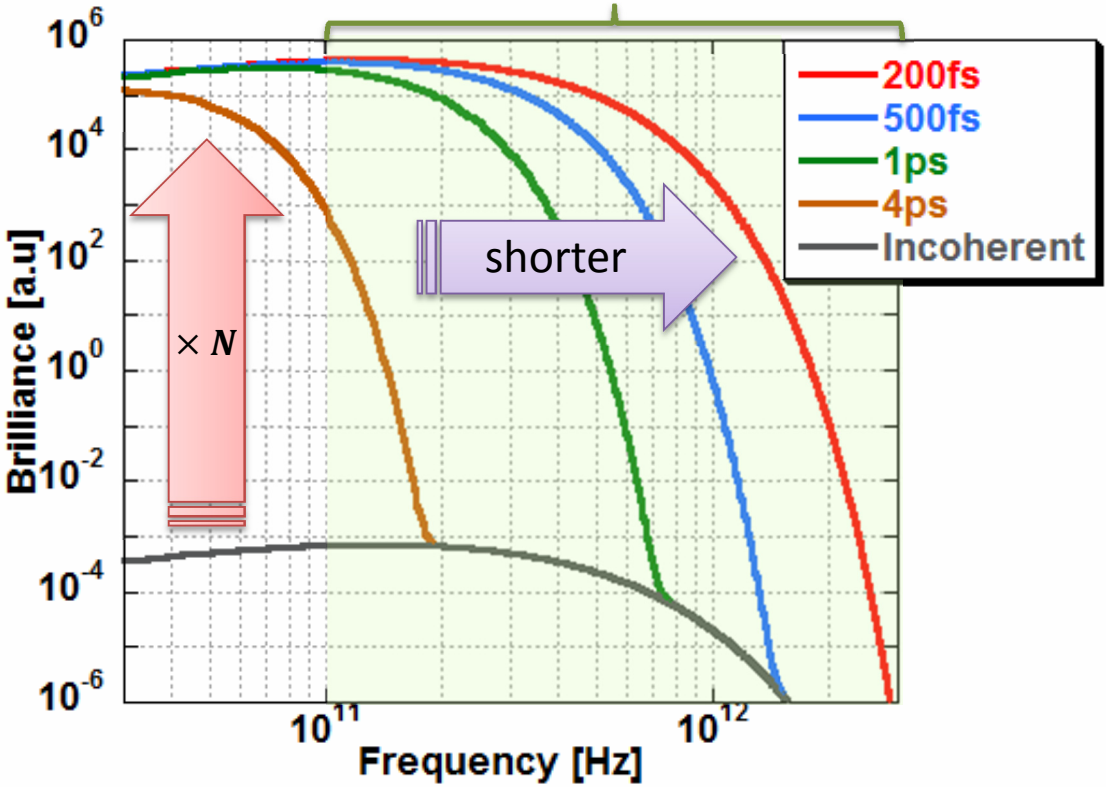
(100pC → N=6 × $\mathbf{10^8}$)

$\sigma > \lambda \rightarrow I_{inc} \propto N$

Incoherent Radiation



THz region



Spectrum of **Coherent Synchrotron Radiation**

(3.7MeV,100pC bunch, calculated by SPECTRA)

$$I_{coh}(\omega) = \left(1 + (N-1) f(\omega)\right) I_{inc}(\omega)$$

when Gaussian $f(\omega) = e^{-(\omega\sigma_z)^2}$

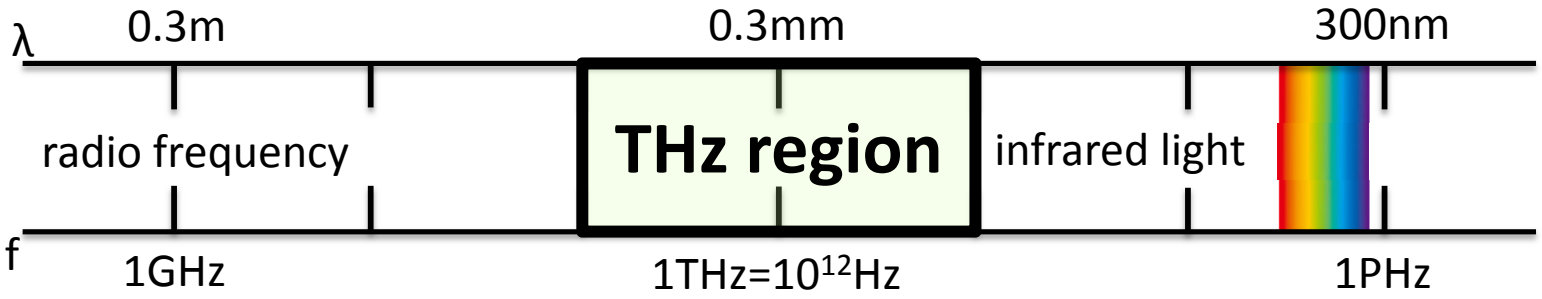
Coherent → $I_{coh} \propto N^2$ /

Shorter bunch brings coherent radiation at **higher** frequency

→ **bunch length estimation**

What's **Terahertz wave**?

Terahertz wave (THz wave) is electromagnetic wave located between radio frequency and infrared light.



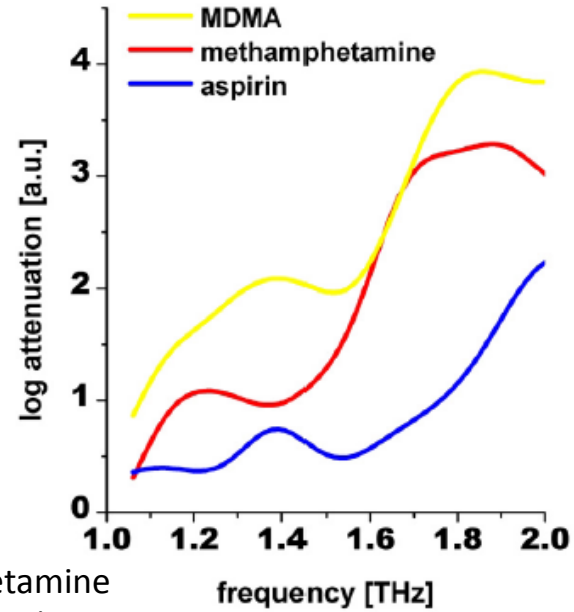
THz Applications

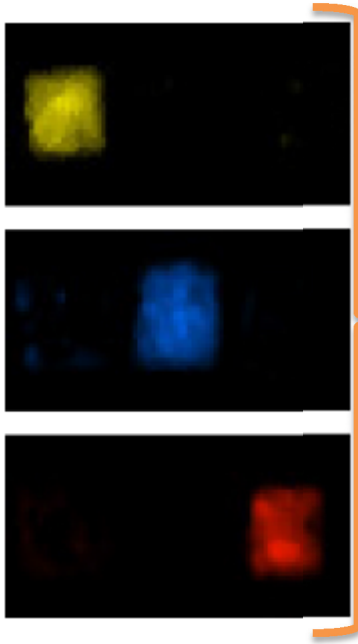
THz Imaging

MDMA (Narcotic)

aspirin (Medicine)

methamphetamine (Stimulant)





distinguishable!

K. Kawase et al.
Opt. Express, 11 (2003)
p. 2549

Motivation

For THz applications,

Compact and **High Power** THz light Source is required.

design

New RF Gun which generates **Ultra-Short Bunch just by itself**

(keeping a certain amount of charge), (without Magnetic Compressors or Acceleration tubes…)

$I_{coh} \propto N^2$ compact

measurement

by **measuring THz radiation,**

confirm new RF gun generates **ultra-short bunch**

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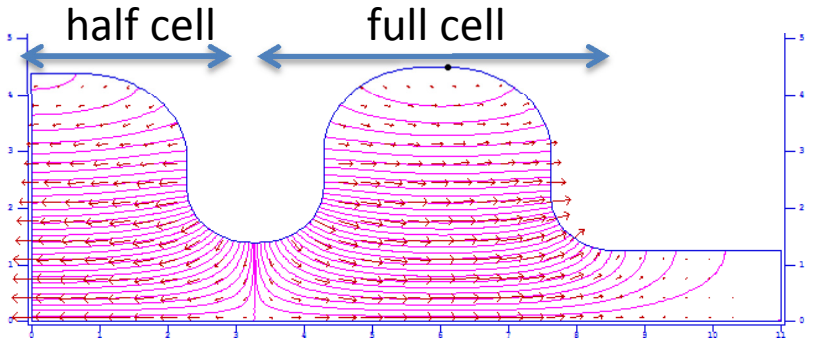
Bunch compression

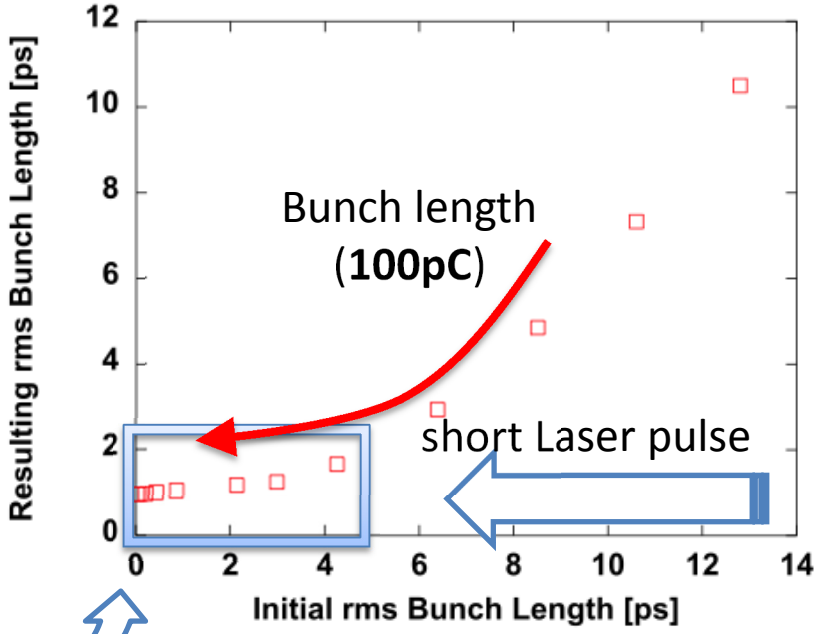
In **conventional** photocathode 1.6cell RF gun,

bunch length could be controlled by the **laser pulse width**.



Cavity structure of the **conventional** RF Gun

However, the bunch length ends up to be more than 1ps due to **space charge effects**.



Bunch length vs Laser pulse width

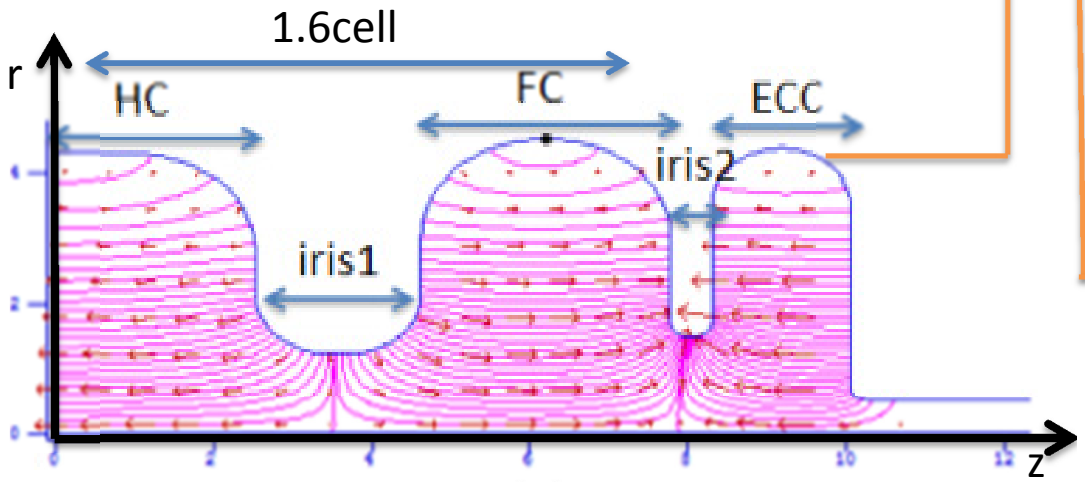
A new RF Gun = ECC RF Gun

We've newly designed an RF Gun.

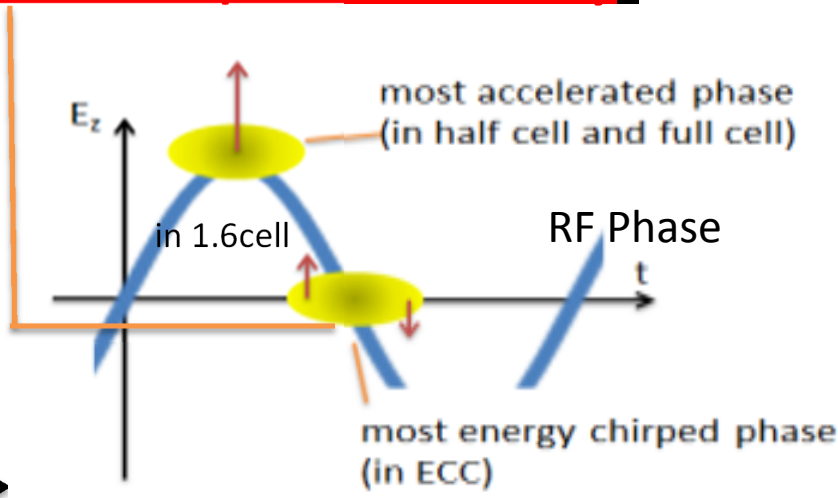
- **Compress the bunch** down to several 100 fs keeping some quantity of bunch **charge**

Energy **C**hirping **C**ell attached **RF Gun** (**ECC RF Gun**)

- In ECC, the bunch energy gets chirped linearly.



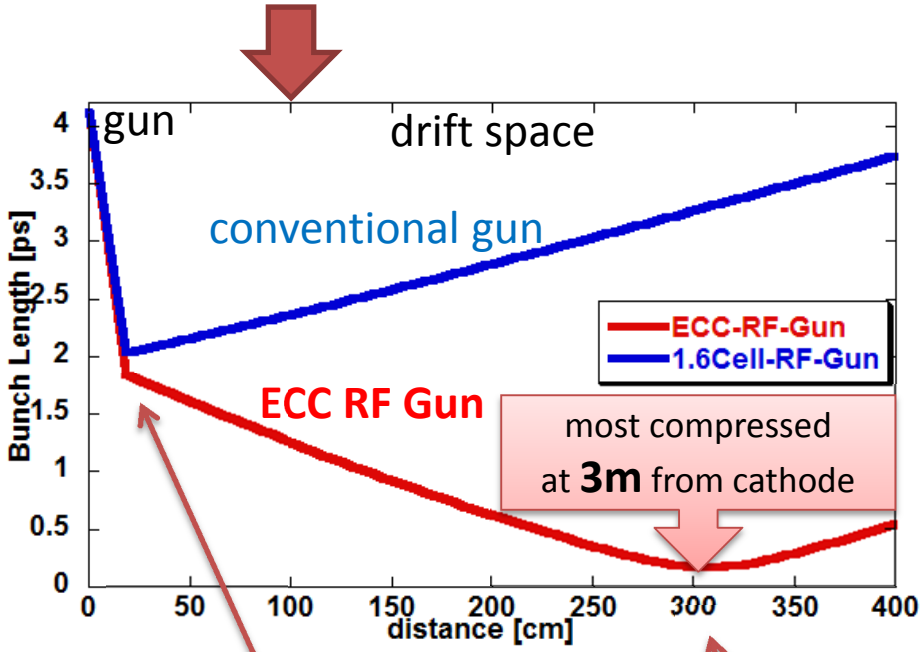
Cavity structure of the **ECC RF Gun**

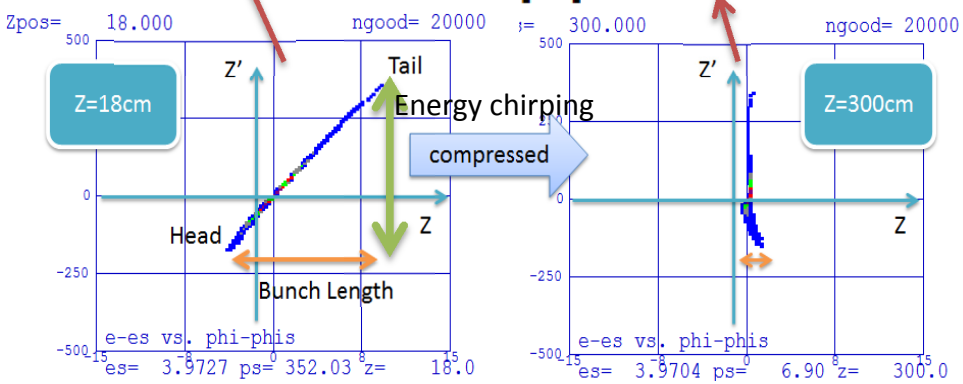


Off-crest RF phase acceleration in ECC

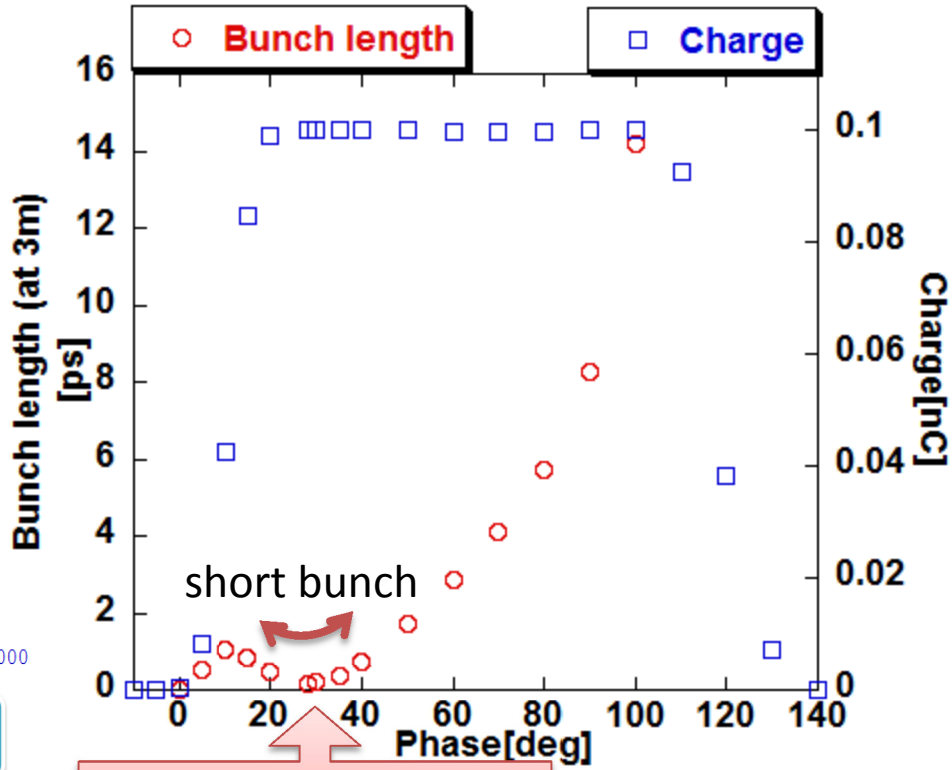
ECC RF Gun Simulation

The Bunch gets compressed by **velocity bunching**.





longitudinal phase-space distribution



simulated by PARMELA and GPT

simulation shows the bunch length gets compressed to **200fs**(rms) with **100pC** bunch !!

ECC RF Gun manufacturing

Confirming **bunch compression** via simulation,

we started manufacturing

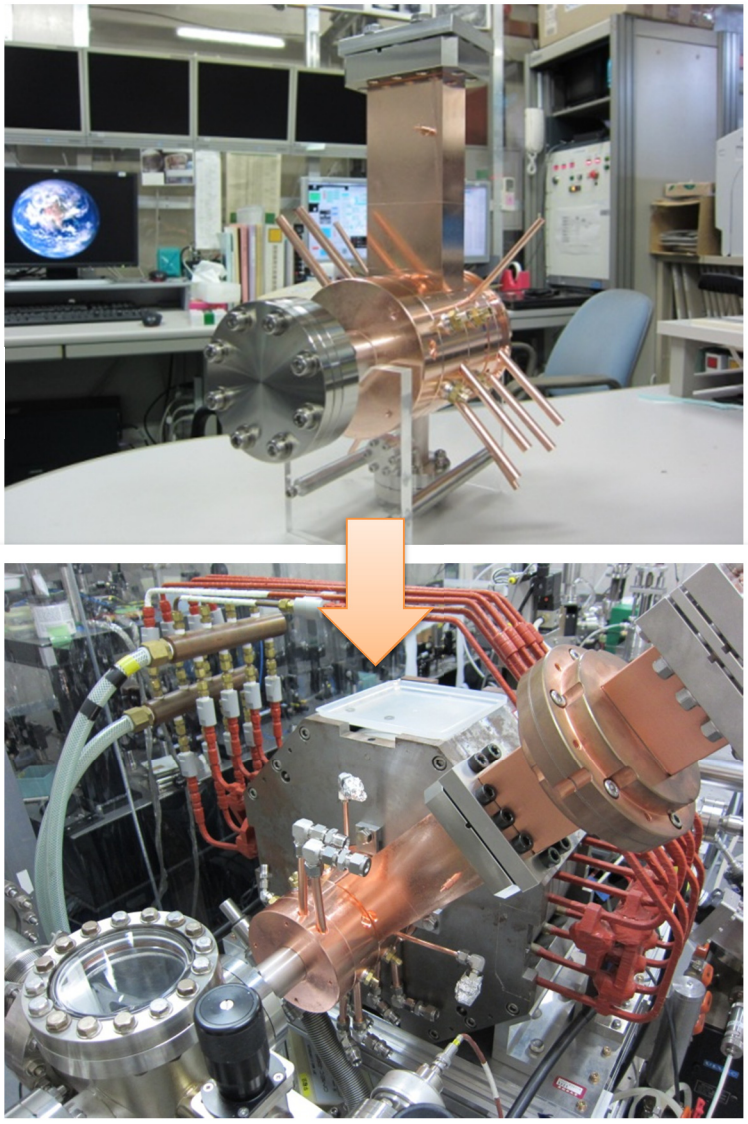
the **ECC RF Gun**.

cavity parameters (simulation)

	ECC RF Gun
Q-value	13932
Frequency (πmode)	2856.066 MHz
Frequency ($\pi/2$mode)	2852.964 MHz
Field balance (E_H: E_F: E_{ECC})	1 : 1 : 1.22

beam parameters (simulation)

	ECC RF Gun
Charge	100pC
Energy	3.7MeV
most compressed point	3.02m
bunch length	180fs (rms)
normalized emittance	5.7πmm-mrad



Installed ECC RF Gun

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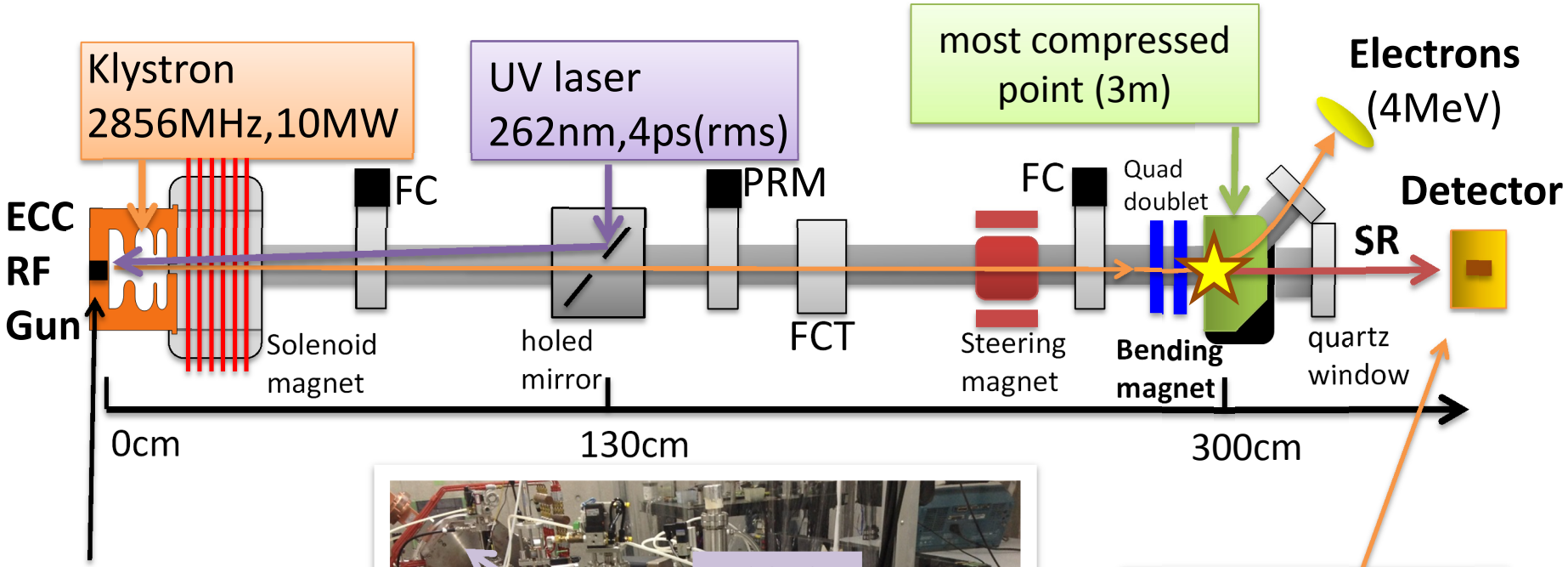
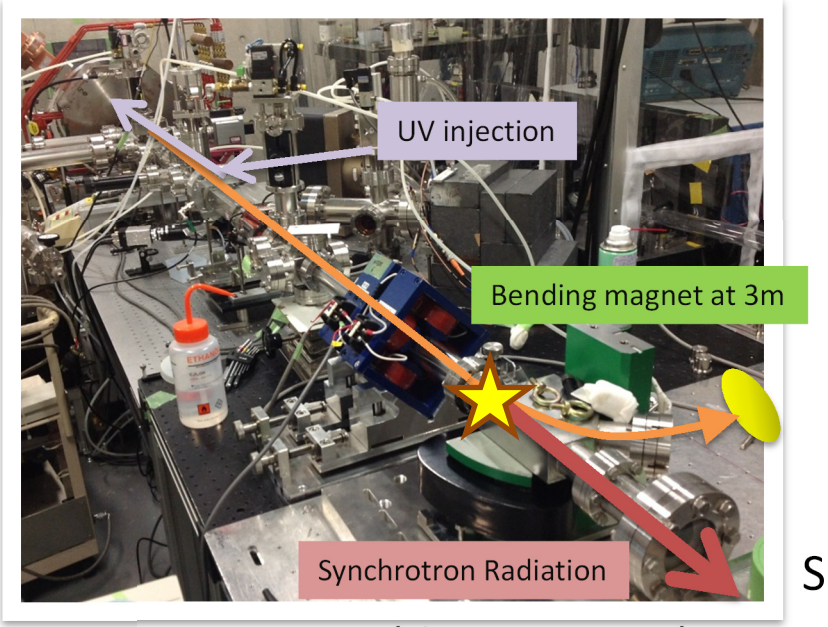
Accelerator System at Waseda



Cs-Te photocathode

degree of vacuum :$\sim 10^{-7}$Pa

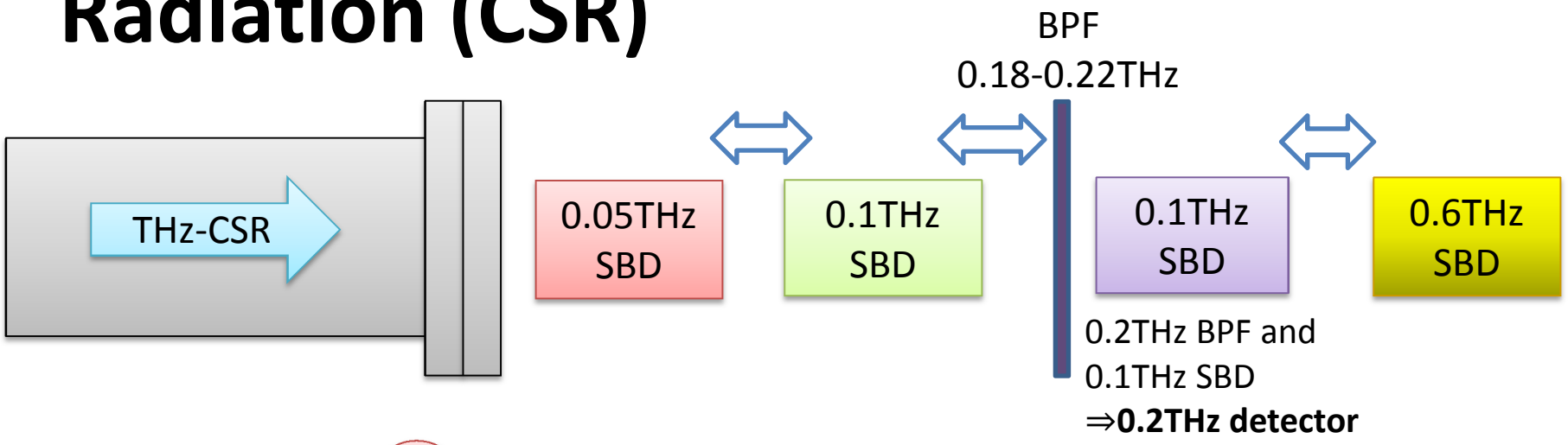
FC : Faraday Cup
FCT : Fast Current Transformer
PRM : Profile Monitor screen

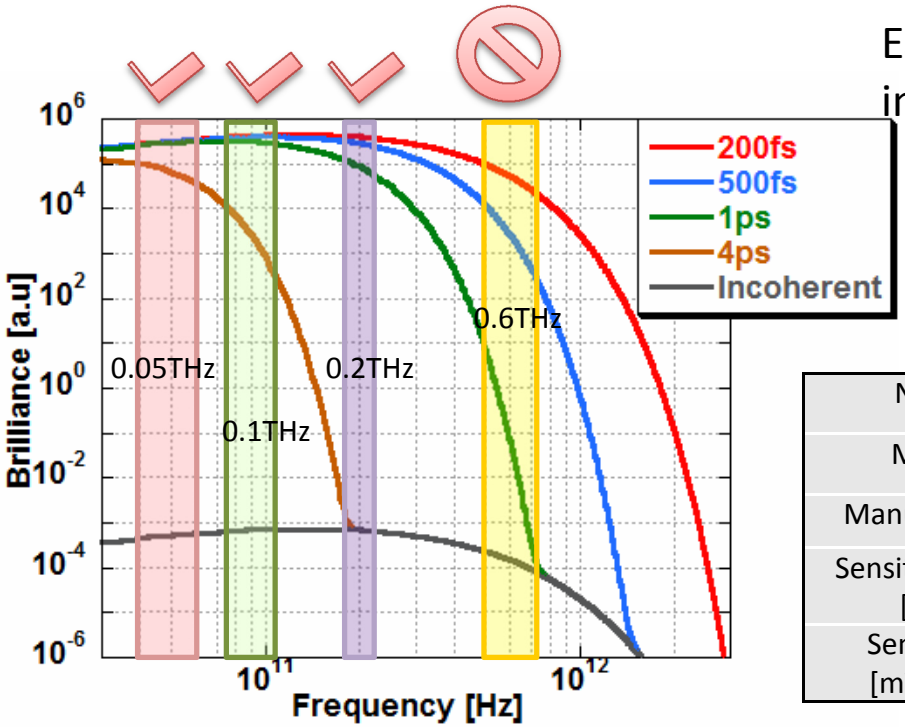


Beam Line (downstream)

Schottky Barrier Diode (SBD)

Detecting **Coherent Synchrotron Radiation (CSR)**





Each detector has **different narrow band sensitivity** in THz region

We can **estimate the bunch length** by measuring frequency of CSR

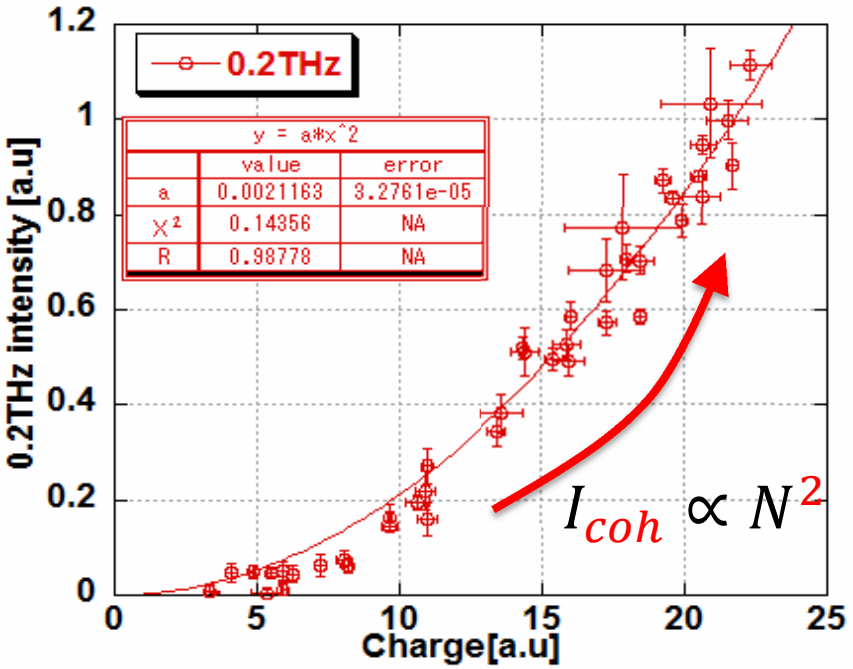
Specifications of detectors

Name	0.05THz	0.1THz	0.2THz	0.6THz
Model	DXP-19	FAS-10SF-01	BPF	WR1.5ZBD
Manufacturer	Millitech	Wisewave	TYDEX	VDI
Sensitive range [THz]	0.04-0.06	0.075-0.11	0.18-0.22	0.5-0.75
Sensitivity [mV/mW]	1000	500	-	750

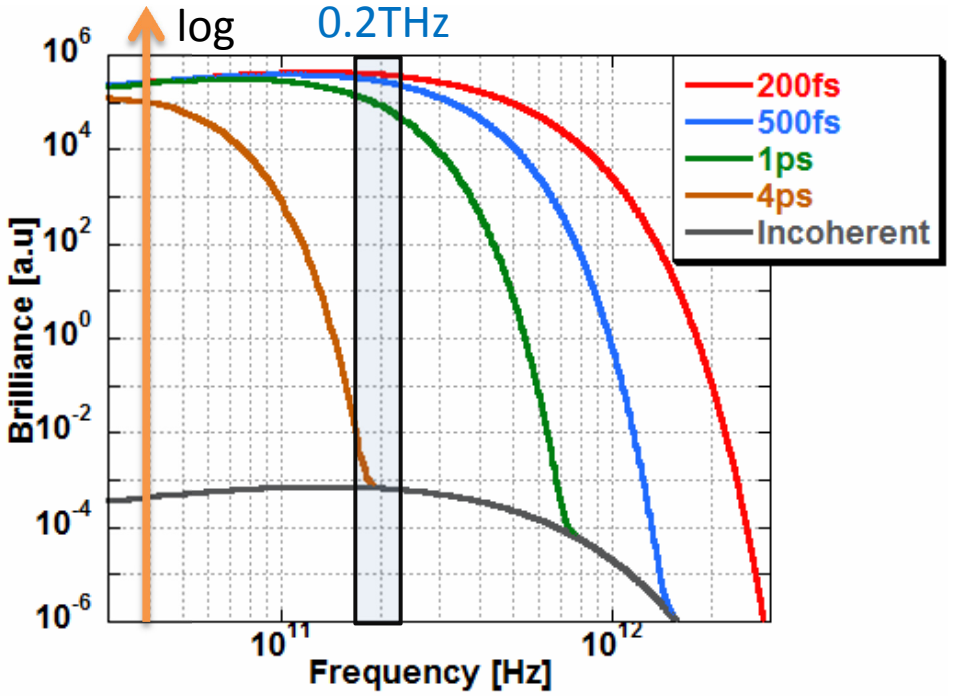
Experimental **Results** 1

We can see **0.05THz**, **0.1THz** and **0.2THz** radiation signal.

confirming **Coherent** Synchrotron Radiation



confirming 0.2THz CSR

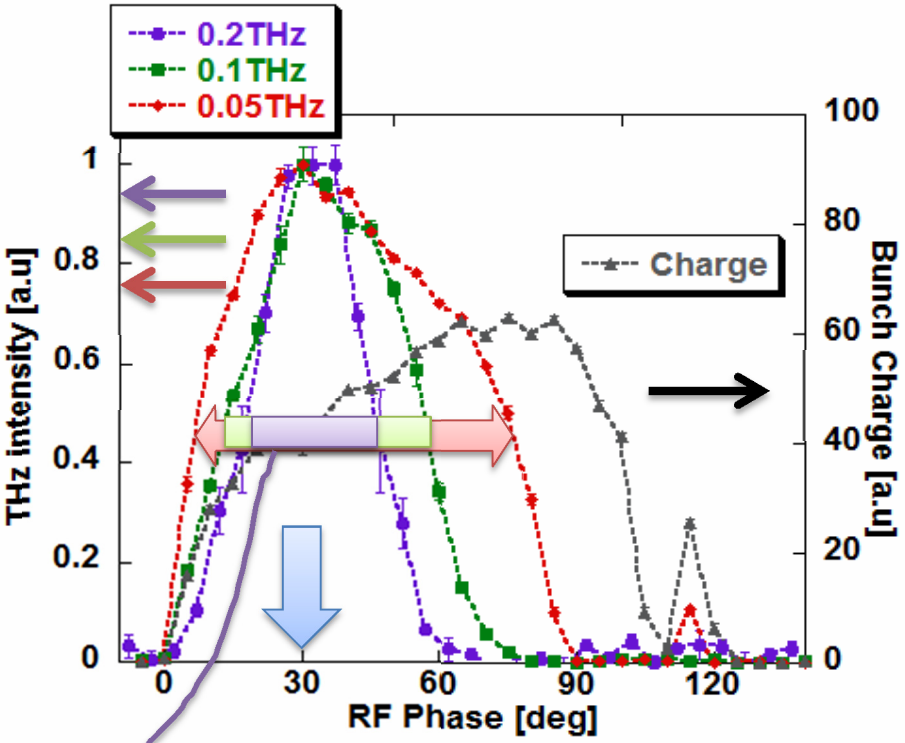


CSR spectrum (calculation)

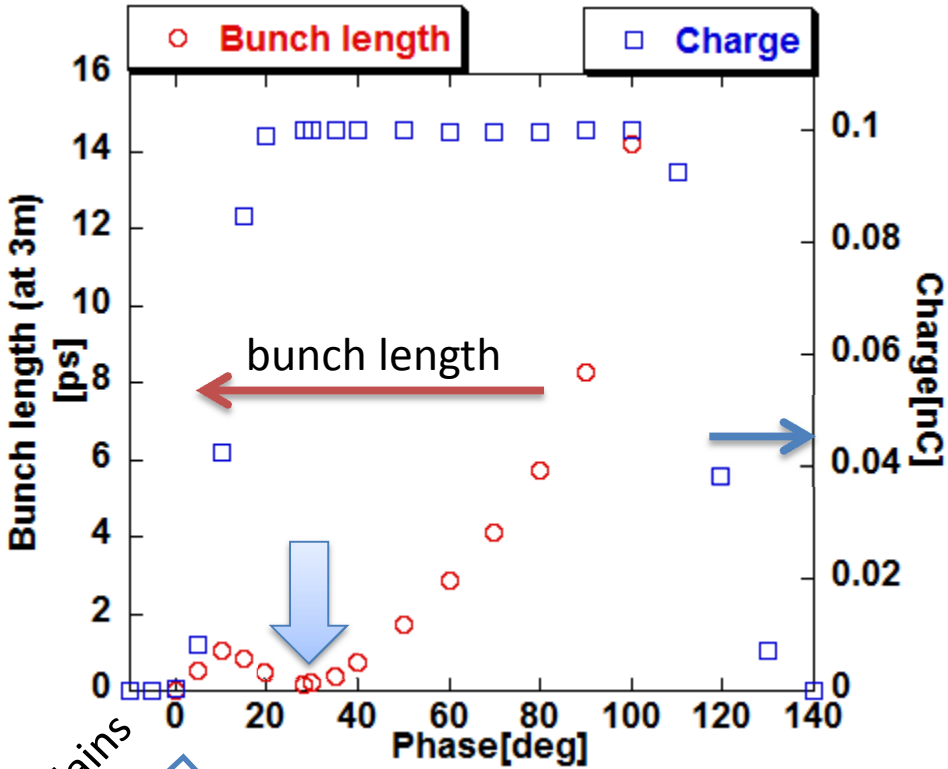
bunch length gets compressed down to **500fs!**

Experimental **Results** 2

also confirming **bunch compression** (depends on **RF Phase**)



comparison of different detectors (**results**)



explains

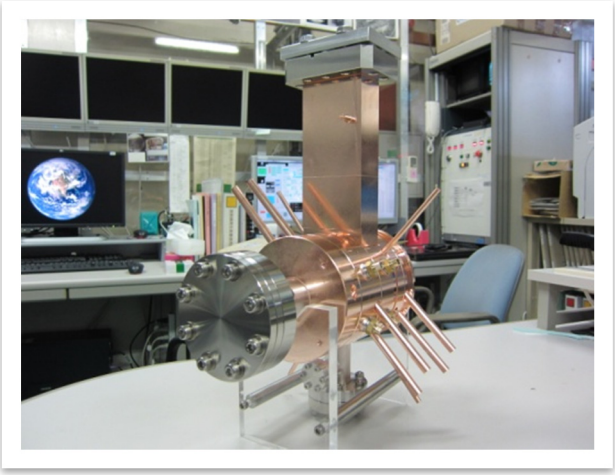
RF phase vs. bunch length (**simulation**)

peak at **30deg**
(most compressed at **30deg**)

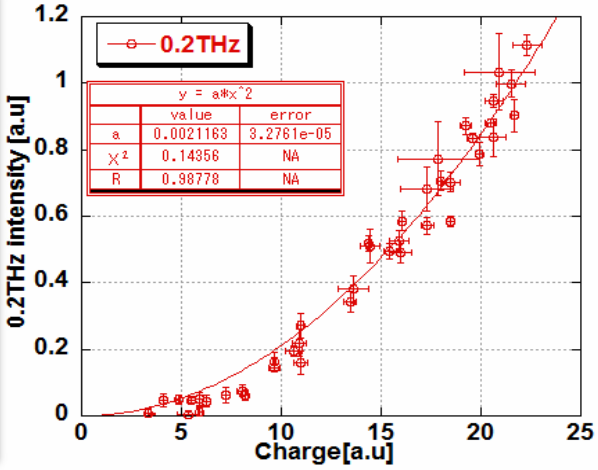
the intensity profile gets **narrower** as the frequency becomes **higher**

Summary

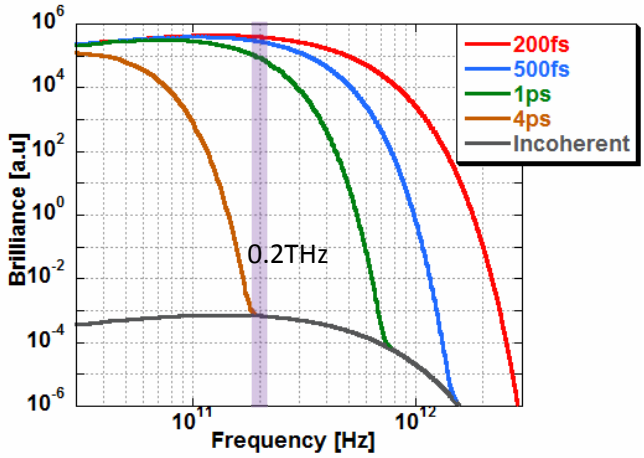
- We have newly designed and manufactured the **ECC RF Gun** in order to achieve **Ultra-Short electron bunch** in a compact system.
- The bunch gets compressed down to **500fs** (rms) because we have successfully measured the **Coherent** THz Radiation at 0.2THz.



ECC RF Gun



Coherent Radiation at 0.2THz



CSR calculation

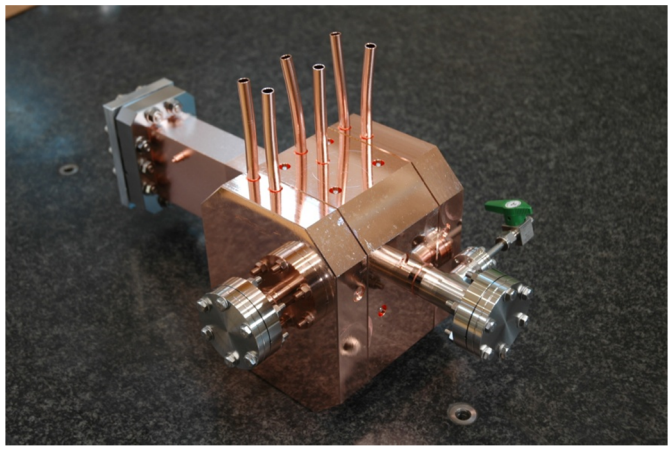
Future Plans

- In the next step, we're going to make an **interferometer** and obtain **frequency spectrum** of Coherent Transition Radiation.

⇨ **Measure** the bunch length more precisely!

- Now an **RF deflector** is being tested in our University.

⇨ **Directly** measuring the bunch length!



2cell **RF Deflector**

Thank you for your attention